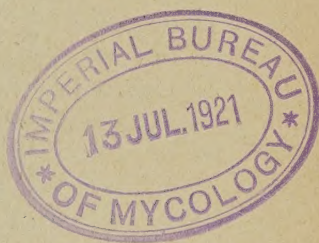

CORNELL UNIVERSITY
AGRICULTURAL EXPERIMENT STATION OF
THE COLLEGE OF AGRICULTURE
Department of Plant Pathology

STUDIES OF THE FUNGICIDAL VALUE OF LIME-
SULFUR PREPARATIONS



Germinating spores of Venturia inaequalis



By ERRETT WALLACE, F. M. BLODGETT,
AND
LEX R. HESLER

ITHACA, N. Y.
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January 23rd, 1911

DIRECTOR L. H. BAILEY,
College of Agriculture
Ithaca, N. Y.

DEAR SIR:—

In accordance with the terms of the Industrial Fellowship agreement with the Niagara Sprayer Company of Middleport, N. Y., I beg to submit herewith the fifth report of the work, with the recommendation that it be published as Bulletin 290.

The work has been performed by Errett Wallace, Fellow, assisted by F. M. Blodgett and Lex. R. Hesler. Some of the work has been done in the laboratory at the College, and some of it in a field-laboratory at Sodus, N. Y. Field experiments were performed in the various orchards about Sodus, and acknowledgment is due the fruit-growers of Sodus for their hearty cooperation. Grateful acknowledgment is due Professor Cavanaugh, of the Department of Agricultural Chemistry, for suggestions and consultation on certain chemical phases involved.

Respectfully submitted,

H. H. WHETZEL,

Professor of Plant Pathology

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STUDIES OF THE FUNGICIDAL VALUE OF LIME-SULFUR PREPARATIONS

PRELIMINARY DISCUSSION

Up to the present time we have been dependent almost entirely on field experiments for progress in the study of the fungicidal properties of various preparations used to control fungous diseases of plants. This method, at best, is very wasteful of time when used alone, but should be used as a final test. An entire season is required to get results from a single set of experiments; we must, therefore, expect that progress in the discovery of new fungicides or beneficial modifications of old ones will be slow until some method is adopted whereby the *fungicidal properties* of various substances can be *studied in the laboratory*. Our suggestion is not that such tests should replace field experiments, but should supplement them by selecting from many possibilities the few probabilities. The latter can then be verified by field experiments. So far as we know, no such method as we are about to describe has been adopted by any botanist or plant pathologist. The chief purpose of this bulletin is to describe some experiments in laboratory methods supplemented by field tests. We believe that by using our new laboratory method we have been able in a few weeks during the winter to select from fifty or more modifications of lime-sulfur solution five which seemed most worthy a field trial. It might also be stated that they were not the five that we should have selected had not the preliminary laboratory tests been made. This indicates that otherwise at least one year more would have been passed with some of the most important points not tested by us.

It is true that many experiments have been conducted to determine the effect of certain fungicidal solutions on spore germination. In most such cases, however, the spores were placed directly in a solution or mixture of the fungicide.* The results, therefore, must be considered as of scientific interest rather than as serving to indicate what these same substances will do after being sprayed and dried on the plant. The latter is the condition in which fungicides, with very few possible exceptions, must prevent infection. According to chemists, lime-sulfur solution, before being applied to the trees consists of soluble sulfids of calcium, chiefly tetra and penta sulfids (CaS_4 and CaS_5). It remains

* Burrill, T. J. (Ill. Agr. Exp. Sta. Bul. 118:553-608, 1907) made most of his tests with the bitter rot fungus in this way. His experiment, No. 11 (l. c. 569), consisting of germination tests on two sprayed cover glasses, is somewhat similar to the method we have employed.

in this soluble form for a short time only. The solution, in contact with the oxygen and the carbon dioxide of the air, soon forms a coating of solid material over the sprayed parts of the plant. The calcium tetra and penta sulfids (CaS_4 and CaS_5) soon become oxidized to thio-sulfate (CaS_2O_3), and later to sulfite (CaSO_3), sulfate (CaSO_4), some free sulfur, and perhaps other compounds. Thus, we must depend finally on comparatively insoluble compounds which are hundreds of times less effective in preventing spore germination than the solution that was applied to the tree. It is therefore evident that a dilution that would give results in the laboratory with spores directly in the solution, might require a concentration several hundred times stronger to control the same fungus on the trees. This is shown, by the experiments recorded in Table 1, to be true in the particular case of lime-sulfur solution in preventing germination of conidia of *Sclerotinia fructigena*.

TABLE 1.—SPORE GERMINATION TESTS IN GREATLY DILUTED LIME-SULFUR SOLUTIONS

Compare with results shown in Table 12

Treatment	Conidia of <i>Sclerotinia fructigena</i> . Per cent germinated	
	Treated	Check
Lime-sulfur sol. 1-20, 000	trace	65
" " " 1-10, 000	o	65
" " " 1- 5, 000	o	80

In these instances a solution testing 32° Beaumé, diluted one part to 20,000 parts of water, prevented more than 99% of germination when the conidia were placed directly in the solution. When tested according to the method we are about to describe, a dilution of 1-100 was somewhat less effective than the 1-20,000 tested by the method that has been commonly employed in this kind of work. Should the question arise as to which method more nearly predicts the results that will occur in actual practice, we would simply say that according to our method of determining this question, a dilution of 1-100 would probably be effective in reducing considerably the percentage of infection by this fungus, but would probably not insure perfect control. According to the other method, a dilution of 1-20,000, 200 times weaker, would almost entirely control it. Of course, it is needless to point out which is more nearly correct.

The first step, involving the fundamental principle in the methods we are about to describe, was taken by Dr. Reddick, of the Department of Plant Pathology, during the winter of 1908 in connection with some class work. This work was described and a few brief general notes on the subject were given in a paper by Dr. Reddick and the senior author ('10) before the American Phytopathological Society at the Boston meeting, December, 1909. Certain modifications of this plan as applied to a specific problem form the basis for this bulletin.

Turning to the fundamental principle in plant disease control, preliminary to a discussion of specific methods of testing the fungicidal values of substances, we have already pointed out that it is not necessarily the compound applied to the tree that acts as a fungicide. Contact with oxygen and carbonic acid gas of the air in most cases doubtless changes the chemical composition and properties of the fungicide before weather conditions favorable for fungus infection arrive. As a matter of fact, it is desirable that this change should take place, at least in a spray that is applied in the soluble form, such as lime-sulfur solution. The more stable, very slightly soluble form is desirable in order to distribute the effectiveness of a given application over a much longer period of time. To illustrate: If lime-sulfur remained in solution as applied, it would probably be extremely effective since the solution is applied several hundred times stronger than is necessary to prevent spore germination. It would be effective, however, for but a very short time, as the first few moments of rain would largely remove it. What we want in a fungicide, then, is a substance that when sprayed on a plant is locked up in stable form from which it is released very slowly when needed, either by the solvent action of meteoric waters or by secretions of solvent substances by the spores (evidently by both, at least in some cases). (See p. 186).

This suggests certain properties essential for a good fungicide, if our hypothesis is correct. First, the substance or substances that go into solution from the dried coating of spray material must have fungicidal value. If this condition is not met it matters little whether the material applied to the plant has or has not fungicidal value. Second, the substances must go into solution in the presence of meteoric water and germinating spores of the fungus to be controlled, in sufficient quantities to prevent germination of these spores. Third, it must not go into solution in such quantities or so rapidly that the material will all dissolve and be carried off with the first short rain, nor in such quantities as to cause injury to the host if the resulting solution is

('10) Reddick D. and Wallace, E. Science, n. ser. 31:798. 1910.

caustic. Fourth, the material must adhere to the plant so that the rains will not carry off the solid particles before they go into solution. From this we see it is not the properties of the solution as applied to the tree that are important in the control of fungous diseases, but those of the final product after its composition has been changed by exposure to atmospheric conditions.

We learn very little or nothing so far as practical results are concerned by testing the fungicidal properties of the solution before it is applied to the tree. A chemical analysis of this solution is of interest to enable us to predict what is probably formed after exposure to atmospheric conditions. But an actual chemical analysis of the dried fungicide would be of greater interest and value.

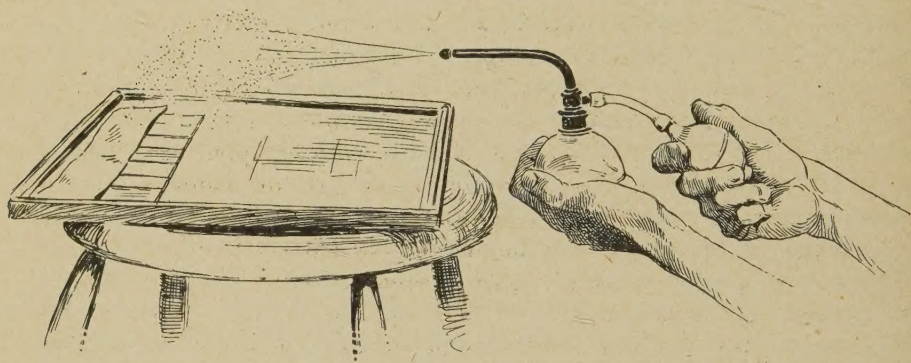


FIG. 79.—*Showing method of spraying slides for fungicidal tests*

With these points clearly in mind, a laboratory method of testing the fungicidal value of a spray and the effect of various modifications of it, has been developed. We do not test the substance that is applied to the plant as found in the spray tank, since it is not in this tank that the substance prevents fungous infections. Rather, we attempt to test the value of the resulting product after it has been subjected to atmospheric conditions as a result of which its chemical composition and properties are in most cases entirely changed.

The method, in brief, is very simple. We spray slides with the material in question (Fig. 79), subject them to atmospheric conditions until the coating of spray has dried thoroughly, place drops of water containing viable spores of the fungus on the sprayed and on unsprayed slides for checks, or preferably carry the check on the unsprayed half

of the same slides, and place in a moist chamber long enough for germination to take place. By microscopic examination, the comparative fungicidal values of various substances can be readily estimated. This alone is not a test for all the essential properties mentioned above. It is, so far as we know, quite an accurate means of comparing fungicidal values of the final product in approximately the form in which it is found when called upon to prevent infection on the host. It does not, however, insure that the fungicidal substances contained therein do not go into solution too rapidly and be entirely carried off with the first rain. Neither does it measure the adhesive qualities of the solid particles themselves.

To make the test of value on these points, it is desirable to subject the sprayed slides after drying to some washing process. Probably no better means could be devised than simply to expose them to rain, which is the agent active on the tree. It is probable, however, that the material would be more easily washed from smooth slides than from the more or less rough surfaces of plants. Just how successfully the properties of adhesiveness and solubility can be tested by this method yet remains to be determined.

In carrying out this work, many difficulties arise and sometimes as yet unexplainable variations in results are noted. Conclusions should be drawn only from a large number of carefully checked experiments. The slightest variations in conditions should be carefully noted. Variations in results sometimes occur on slides apparently treated alike. In our work, however, the results are quite uniform in a single experiment involving slides sprayed at one time and when spores from the same source are used for cultures. This suggests that some minor variations in conditions are probably responsible for the variations in results. We have reason to believe that the viability of the spores used greatly influences the results. This seems to vary with the age of the culture from which they are taken, and probably with the medium on which they are grown. It was noticed that, in the case of spores which gave a high percentage of germination in the checks, a stronger solution of the fungicide was necessary to entirely prevent germination than when their viability was low. It is quite probable that this is also a factor influencing infection of host plants by fungi. This is another reason why positive conclusions should not be drawn from a single season's spraying experiments. If the crop of spores distributed at a given time is very viable, a greater concentration of the fungicide will probably be necessary to insure control than if their viability is low.

Although the method outlined above seems comparatively simple in routine, much care must be exercised in all phases of the process

in order that reasonably correct conclusions may be reached. It is almost needless to say that care must be taken in spraying the slides. They may be spread out on a tray and one end covered with a ruler so that none of the spray material is permitted to fall upon the check end. The atomizer is not held at right angles but parallel to the surface of the slides, as shown in Figure 79. Whenever the spray contains

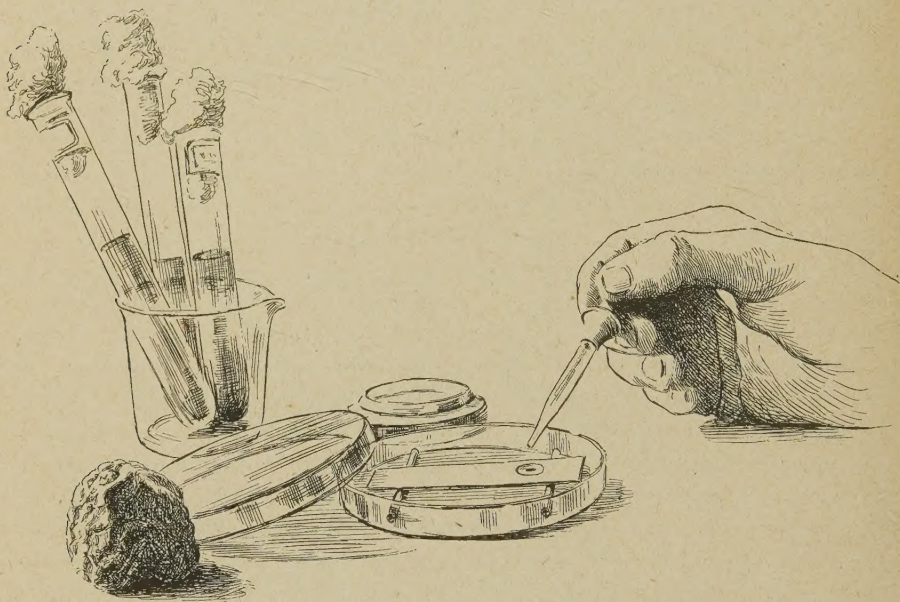


FIG. 80.—Placing the drop of water containing spores of the fungus on the sprayed end of the slide. Another drop will be placed on the unsprayed end, some water poured in the petri dish, and the cover placed on the latter, thus leaving the spore cultures in a moist chamber. Pure cultures of the fungi from which the spores are obtained, are growing in the test tubes at the left.

any sediment or precipitated material it should be kept constantly agitated. The bulb of the atomizer must be squeezed rapidly in order to obtain a fine mist and to distribute the drops equally over the surface of the slide. If large drops are deposited in place of small ones the results on germination are misleading, for at that particular point directly on the drop the percentage of spore germination is greatly reduced, while on the uncovered spaces much more germination will be permitted than on any part of a slide evenly sprayed. In general, it may be

said that the slides should be so sprayed that the coat of material is similar to that on the plant as it is sprayed in the field.

The slides should be allowed to dry in order to permit any chemical changes to occur that are likely to be induced by exposure to atmospheric conditions. The importance of this is discussed on page 167. In brief, it may be said, that the same chemical changes which take place on the leaf, previous to infection, must be allowed to occur on the slide in the laboratory before the spores are placed to germinate. This more nearly duplicates natural conditions, and the results on germination should practically indicate the relative fungicidal value of the spray materials in question. Each slide, when thoroughly dry, is placed in a petri dish containing enough water to keep the air well saturated. For convenience each may be supported by short pieces of glass tubing (Fig. 8o). A mixture of spores and water is made in a watch glass, the same containing enough spores so that thirty or forty might be counted in a single field of a 16 mm. objective. In our experiments, conidia of the apple scab fungus (*V. inaequalis*), New York apple tree canker fungus (*Sphaeropsis malorum*) and *Sclerotinia fructigena* conidia, (brown rot of peach), were used almost exclusively. In the first case, spores were taken from matured spots on the fruit or leaf, and in the second case they were taken from well-developed cankers. In general, the older and more nearly mature conidia of *Venturia* were more viable than those of comparatively recent formation. In our experiments, the most viable conidia of *Sclerotinia* were obtained from potato agar cultures of the fungus that were eight to twelve days old. These were thoroughly stirred in water, making up a quantity sufficient to treat all the slides to be compared at one time, and the drops were placed on the slides with a dropper (Fig. 8o). This method should insure equal distribution of spores both as to number and viability to all slides. This is important for two reasons: first, the viability of spores even from different parts of the same culture may vary; second, their distribution as to number is important, for when the spores in the culture are very numerous their viability is found to be much reduced. This is evidently due to the toxic effect of their own secretions.*

* Burrill, T. J. (Ill. Agr. Exp. Sta. Bul. 118: 1. c. 568-569. 1907) found that it required a stronger solution of copper sulfate to prevent germination of a large than of a small number of conidia of *Glomerella rufomaculans*. These spores seemed to have a cumulative effect on the soluble copper. The results would probably be different, however, if the spray material were in the insoluble form since the greater number of spores would probably exert a greater solvent action on the fungicide. See p. 186.

As stated above, the slides were placed in a moist chamber and set aside for germination. Twelve to twenty-four hours is usually sufficient time to allow for germination of all the viable spores, but this will vary with the species. In these experiments, it was found that no increase in percentage of germination occurred after twelve to fifteen hours, so that one count was satisfactory. In making the counts, it is well to bear in mind that it is here that the value of the fungicide is to be determined. It is desirable that accurate counts of several fields on each slide should be made until the operator has gained sufficient skill to enable him to estimate very accurately, without counting, the percentage of germination. After this, the time required to make actual counts of every field might be spent more profitably in running through a larger number of slides, unless an unlimited amount of time is available. Conclusions drawn from results on only a few slides of each treatment are not reliable, no matter how accurately the counts have been made; that is to say, a few slides may happen to run much lower or higher than the average of a large number under the same treatment and, (by the law of averages), conclusions could not be based on such variations as might arise from slight errors in making the counts. In making these counts, the objective should be adjusted so that the fields of spores in focus are those which are nearest the spray material on the slide. In making counts on the unsprayed ends of the slides, no special precaution in selecting the fields need be taken since germination will be uniform in all parts of the drop, except perhaps at the surface in contact with the air where external influences might interfere.

Five representative fields were usually selected and in each case no less than fifty spores were counted. Whenever the fields showed a wide variation in percentage of spore germination, a larger number of fields were counted until satisfactory results were obtained. These were then compared with counts made on a number of the similarly treated slides and in a majority of such cases the percentages were consistent, varying a little perhaps with the individual spores and the relative amounts of spray material present to affect them.

TESTS WITH LIME-SULFUR SOLUTION ALONE

Lime-sulfur solution has been found in the laboratory to be only fairly effective as compared with other combinations in the prevention of spore germination. However, it seems to reduce germination to a considerable degree, the percentage of germination being lower, of course, with the stronger solutions and higher with the weaker ones. Whenever a high percentage of the checks germinated, the corresponding

percentage of germination on the sprayed end of the slide was higher than in cases in which the former showed low viability. In other words, the more viable spores simply require a stronger concentration to prevent their germination. (See Pl. 1, Figs. 3, 4, 5.)

At this point, it may be well to note the relative viability of the spores of the different species used in these experiments. Tables 2 and 12 show that spores do not germinate at parallel rates in the same concentration. This was not occasional nor accidental, but has been consistent in most of our tests. Spores of *Sphaeropsis malorum* in lime-sulfur 1-50 germinated to the extent of 74%; those of *Venturia inaequalis* (conidia) germinated in the same strength solution to the extent of 12%, while those of *Sclerotinia fructigena* (conidia) showed only a trace of germination. A similar gradation is observed with respect to lime-sulfur solution in practically all concentrations used, and it is seen that in almost every case pycnosporos of *Sphaeropsis malorum* are far more resistant than the *Venturia* conidia or the *Sclerotinia* conidia. Field tests further strengthen the conclusion that lime-sulfur solution alone is only fairly effective as a fungicide. Scab on Greenings was reduced only from 79% to 29% by lime-sulfur 1-30 alone. (See page 178 for comparison with lime-sulfur combined with lead arsenate.)

TESTS WITH ARSENATE OF LEAD ALONE AS A FUNGICIDE.

According to laboratory tests, lead arsenate alone seemed to have rather weak fungicidal value. One-half gram to 100 cc. reduced germination of the scab fungus conidia from 68% to 35%; two grams to fifty cc. reduced brown rot conidial germination from 78.8% to 56.9% (see Pl. Figs 3 and 7), and germination of *Sphaeropsis* spores from 87% to 70%. On the trees alone, however, arsenate of lead could be expected to give consistently better results than other fungicides having poorer adhesive properties, even though the fungicidal properties of the latter may be stronger. (See page 177 for explanation.)

Arsenate of lead alone has been found in field experiments to reduce apple scab considerably and, in mild cases, to control it fairly well. In the orchard referred to on page 180, arsenate of lead alone, 2 pounds to 50 gallons, reduced the scab on Hubbardstons from 94% to 29%, while lime-sulfur 1-40 with arsenate of lead reduced it to 3.0%. According to these tests, the arsenate of lead alone controlled scab about as effectively as lime-sulfur alone (see p. 180); but neither used alone was so effective as the two combined. Waite ('10) reports that arsenate of

('10) Waite, M. B. U.S.D.A., Bur. Plant Ind. Cir. 58: 1. c. 12. 1910.

EXPLANATION OF PLATE I.—Photomicrographs showing the result of spore germination tests on slides variously treated. Conidia of the peach rot fungus, *Sclerotinia fructigena*, were used. Forty-eight hours were allowed for germination. Magnification the same in all cases.

FIG. 3.—On unsprayed slide.

FIG. 4.—On slide sprayed with lime-sulfur solution diluted 1-100 with lead arsenate added, three pounds to fifty gallons. Note that germination was entirely prevented. Compare with Fig. 3.

FIG. 5.—On slide sprayed with lime-sulfur solution diluted 1-100 without lead arsenate added. Note that although germination and growth was much reduced, it was not entirely prevented, as in Fig. 4, in which lead arsenate was added.

FIG. 6.—On slide sprayed with lime-sulfur 1-100 + lead arsenate precipitated by carbon dioxid. Showing that germination was entirely prevented, as in Fig. 4, in which the solution had not been precipitated.

FIG. 7.—On slide sprayed with lead arsenate alone. Note that growth was much inhibited, but a large percentage germinated.

FIG. 8.—On slide sprayed with sediment from Niagara lime-sulfur heavy grade, diluted 1-50. Showing about the same result as with the clear solution diluted 1-100, Fig. 4.

FIG. 9.—On clean slide, in water transferred from slide sprayed with lime-sulfur 1-50, on which it had stood for forty-eight hours. (See p. 186.) Note that much germination was permitted although growth was somewhat checked.

FIG. 10.—On slide sprayed with sulfur, 1 gram to 50 cc. of water.

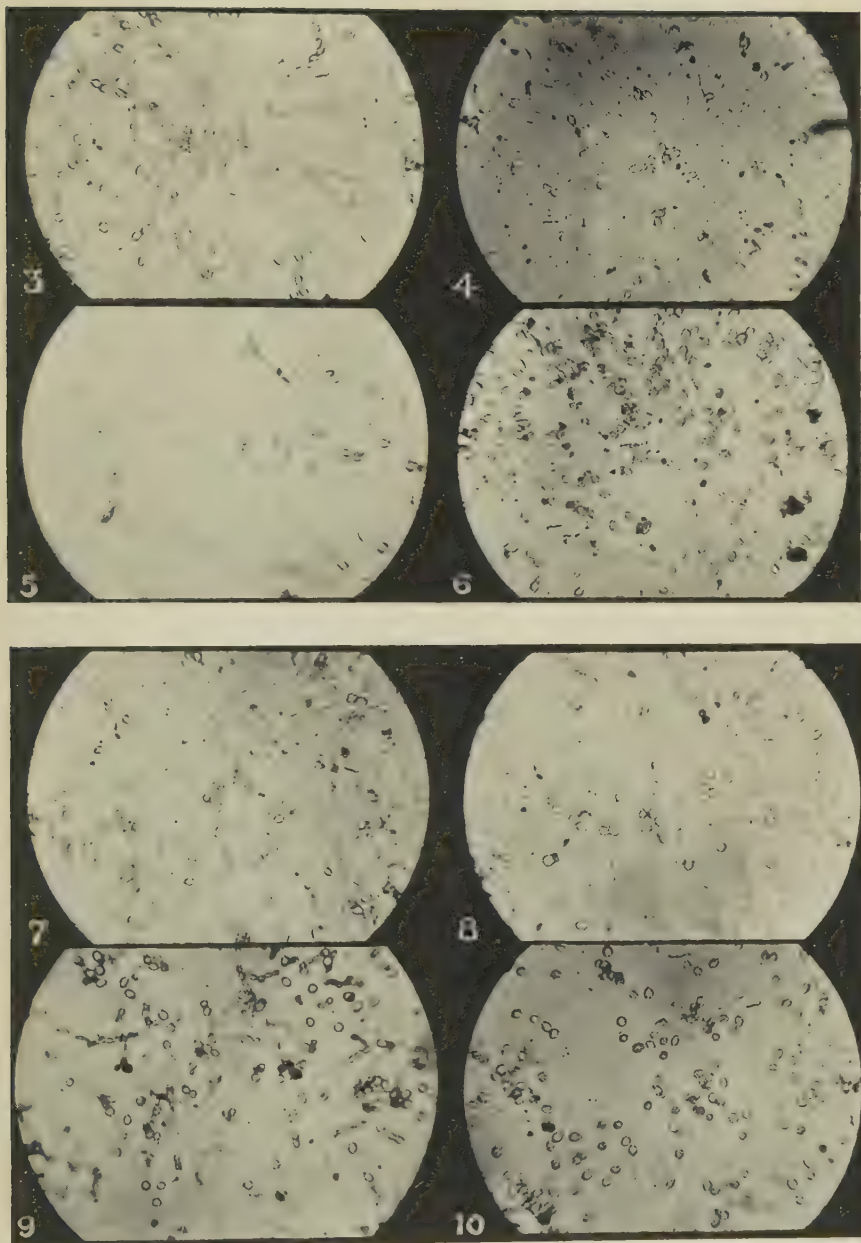


PLATE I. Photomicrographs showing the result of spore germination tests on slides variously treated. Conidia of the peach rot fungus, *Sclerotinia fructigena*, were used. Forty-eight hours were allowed for germination. Magnification the same in all cases.

lead alone controlled fly speck, smut fungus,* fruit spot, leaf spot, etc., in Virginia in 1909 just as did the other fungicides used. It has further been noted by Taylor ('09) that arsenate of lead alone has controlled peach rot and he intimates that scab was also controlled. Taylor attributes his results to the control of the curculio, whose puncture furnishes an important point for rot infection, but the results probably were also due largely to the fungicidal value of lead arsenate itself. If scab infection was prevented, it could not well be attributed to the control of curculio.

After careful consideration of all these notes, it seems evident that in case of mild attacks of fungi or of the attacks of some fungi that are very easily controlled, arsenate of lead alone may be quite effective in preventing infection. On the other hand, in cases of severe attacks by resistant fungi the use of a stronger fungicide is necessary for good results. Under the conditions obtaining at Sodus, N. Y., during the past season (1910), the attack of scab was sufficiently obstinate to necessitate the use of a stronger fungicide. On the other hand, in the fungicidal tests made with lead arsenate in the laboratory, spore germination was prevented to such a slight extent that it hardly explains, on the toxicity basis, the results that have been obtained in spraying experiments. It will be noted that even the *Sclerotinia* conidia, which are in general prevented from germinating by quite weak fungicides, gave a germination (in arsenate of lead) of 57% with checks at 79%. Yet Mr. Taylor ('10), as stated above, reports quite satisfactory control of peach rot by lead arsenate alone; and, in our experiments on apples, lead arsenate alone reduced scab much more than would be predicted from our laboratory tests. It appears evident that we must look for some explanation of its action aside from that of preventing spore germination.

The following hypothesis might be suggested as an explanation of the fungicidal value of lead arsenate when used in field work; and the principle might also apply to some other fungicides. From the fact that such a large percentage of germination has been permitted on slides sprayed with this substance, it would seem improbable that the simple prevention of spore germinations would be as effective on the trees as it has seemed to be in some cases. Let us suppose, however, that the surface of the fruit or leaf is so completely coated with the substance that a germinating spore before entering the host tissue must actually bore its way through the thin film of lead arsenate. It is doubtless

* So in original.

('09) Taylor E. P. The Fruit Grower. Oct. 1909.

('10) Taylor, E. P. The Fruit Grower, Feb. 1910:17.

true that many spores could germinate in water above the film of lead arsenate whose germ tubes could not bore through that film to reach the underlying tissue, since in so doing they would come in so much closer contact with the toxic substance. Infection on parts so coated might thus be prevented even though the spores had germinated.

This suggests the consideration of the possibility that there are cases in which a fungicide protects from infection without preventing spore germination. Lead arsenate having such remarkable adhesive qualities, if very thoroughly applied would be effective for some time in furnishing this kind of protection. On surfaces that are growing rapidly, however, new unprotected areas would soon become exposed, for which reason only partial protection could be expected (even though the surface were entirely coated at the time of spraying) if the infection period occurred some time after the application. On the other hand, if the fungicide effectively prevents germination of the spores, small areas thus exposed by growth might also be protected from infection, since a single drop of water may cover both sprayed and unsprayed areas. It is probable, therefore, that though the above hypothesis be true, the only fungicide that will be reliable is the one that protects by preventing spore germination.

TESTS OF THE EFFECT OF THE ADDITION OF LEAD ARSENATE TO THE LIME-SULFUR

This is a question of great economic importance, especially in spraying for fungous diseases of the apple. We must use a fungicide that can be combined with a poison to control the codling moth. When lead arsenate is added to lime-sulfur, a chemical change takes place and lead sulfid and calcium arsenate are formed, according to Bradley and Tartar ('10). It had been feared by many that such a reaction would weaken the fungicidal value of the lime-sulfur solution, since some of the soluble sulfur is precipitated. Hereagain the error was due to the mistaken idea that soluble sulfur is the all-important ingredient. Contrary to these conclusions, our laboratory and field tests during the current season have proved conclusively that the addition of lead arsenate not only does not decrease the fungicidal value of lime-sulfur solution but greatly increases it. See Pl. 1, Figs. 3, 4, 5.

In our laboratory, over 250 experiments on this point were performed, using the spores of three different fungi. Table 2 gives only the total averages of all like experiments. For a record of the individual experiments, see Table 12.

('10) Bradley, C. E. and Tartar, H. V. Jour. Ind. and Eng. Chem. 2:328. 1910.

TABLE 2.—SHOWING EFFECT ON SPORE GERMINATION OF ADDITION OF ARSENATE OF LEAD TO LIME-SULFUR SOLUTION.
Giving averages of all like experiments.

Treatment	Sp. <i>malorum</i> % germinated			V. <i>inaequalis</i> % germinated			S. <i>fructigena</i> % germinated		
	Treated + lead arsenate	Check	Treated	Treated + lead arsenate	Check	Treated	Treated + lead arsenate	Check	Treated
L. S. 1-200.....									
L. S. 1-150.....									
L. S. 1-100.....	41.6	95	90.3	0	85		1.5	51	7
L. S. 1-50.....	21.5	88	74	0	66		0	49	11.5
L. S. 1-30.....	8.3	91	64	0	42		t	73	9
L. S. 1-20.....	4	80	54	0	86				
L. S. 1-200, pptd.....									
L. S. 1-150, pptd.....									
L. S. 1-100 pptd.....									
L. S. 1-50, pptd.....									
1-200 + lime.....							.5	54	6.6
1-100 + lime.....							0	66	5
1-200 + lime, pptd.....							t	84	7.2
1-100 + lime, pptd.....							0	50	3.6
1-100 + lime, pptd.....							t	45	49.7
1-200 + iron sulfate.....							0	62.5	56.6
1-100 + iron sulfate.....							0	76.2	59
L. S. 1-200 + iron sulfate, pptd.....							0	65	0
Sediment 1-100.....							7-7	61.3	43
Sediment 1-50.....							0	72	3.5
Self-boiled L. S. 4-4-50.....							6.5	80	80
							9	79	3.5
							4.3	90.7	17.2
							0	13	4.2
									6.2
									52.5

Note—pptd=precipitated with CO₂
t=trace of germination
0=no germination

On *Venturia conidia*, lime-sulfur alone, diluted 1-30, was much less effective than a dilution of 1-100 with arsenate of lead added. A few tests were made using lime-sulfur alone, diluted 1-20 and 1-10, and in each case a few spores germinated. A dilution of 1-100 with arsenate of lead added prevented all germination, while the checks averaged about 70%. On conidia of the brown rot fungus, *Sclerotinia fructigena*, a dilution of 1-200 with arsenate of lead permitted less than 2% germination, while 1-50 alone allowed 9%. Again, when spores of *Sphaeropsis malorum* were used, lime-sulfur 1-100 with arsenate of lead reduced germination more than a 1-20 dilution of the lime-sulfur solution alone. The table shows that these spores were much more resistant to the spray than either of the other fungi, but the results varied with the treatment in a manner parallel with the results when the other fungi were used. These tests would seem to indicate that the fungicidal value of lime-sulfur solution is more than doubled by the addition of the usual amount of lead arsenate (2 pounds to 50 gallons).

Field tests have further strengthened this conclusion. In Mr. Baxter's orchard, Sodus, N. Y., Greening trees sprayed with lime-sulfur solution alone, diluted 1-30, reduced scab from 79% to 29%, while the same dilution with 2 pounds arsenate of lead added to 50 gallons reduced it to 10%. On Duchess pears, in Mr. Johnson's orchard, Sodus, N. Y., results were still more striking. From counts made early in the season, it was found that early infection was reduced from 100% to 74.2% by lime-sulfur solution, 1-40, alone, and to 8.5% by the same concentration applied at the same time with arsenate of lead added at the rate of 2 pounds to 50 gallons.

Here the question may arise, "Is the increased efficiency gained by combining the two substances due to the chemical reaction induced, or to the fungicidal value of the lead arsenate itself?" In the discussion on the fungicidal value of lead arsenate, page 175, it will be noted that according to both field and laboratory tests this substance has some fungicidal value but hardly sufficient to account for the marked increase in the efficiency of lime-sulfur due to its addition. The additional effectiveness on the trees might be accounted for by the superior sticking qualities of arsenate of lead, but even this, we are told, is destroyed by the reaction. If the products of the reaction are lead sulfid and calcium arsenate, then either one or possibly both of these should prove to have strong fungicidal properties. In this connection, lead sulfid was tested by laboratory experiments and found to have rather weak fungicidal properties. A dilution of 2 grams per 100 cc. reduced the germination of *Venturia conidia* from 61% to 18%, 1 gram to 100 cc.

from 53% to 31%, and $\frac{1}{2}$ gram to 100 cc. from 42% to 17%. Calcium arsenate, unfortunately, has not yet been tested.

TEST OF THE EFFECT OF THE ACTION OF CARBONIC ACID GAS ON THE FUNGICIDAL VALUE OF LIME-SULFUR SOLUTION

Until quite recently, the gas sprayer has been popular with many growers. It is well known that in the machine the power is furnished by carbonic acid gas, which is purchased in condensed form under high pressure in strong iron tubes. The gas is gradually released as needed from this tube into the air-tight tank containing the spray material. The pressure thus produced furnishes the power. After the introduction of lime-sulfur as a fungicide, it became known that carbonic acid gas thus brought into contact with soluble sulfur largely changed its composition. A chemical reaction takes place, in which the sulfids of calcium are broken up and insoluble compounds are formed. When this gas (CO_2) is passed through lime-sulfur solution in a test tube it will be noticed that in a very few moments the solution, which was perfectly clear, becomes cloudy and in a short time the soluble sulfur is thrown down in the form of a whitish precipitate, which, on standing, soon settles to the bottom, leaving the clear liquid, probably mostly water, above. It was, of course, naturally predicted that this action would destroy the fungicidal value of the preparation. If soluble sulfur were the active agent it is certain that this prediction would hold true. On page 167, however, we have given reasons why it is not soluble sulfur as applied that is the active agent, but rather the comparatively insoluble products into which it changes shortly after exposure to atmospheric agencies. Considering this, it occurred to us that possibly the insoluble product formed by the action of the gas previous to application would be as effective a fungicide as the insoluble product formed on the tree by exposure to the air. We hoped, also, that if this should prove true we might be able to use it in this way on tender foliage, such as that of the peach, and avoid all danger of injury. It might be noted here that this later proved true when lime-sulfur solution alone was used, but when arsenate of lead and lime-sulfur together were thus acted on by the gas, serious burning of peach foliage resulted, evidently due to the formation of soluble arsenic. (See Cornell Bul. 288: 1. c. 120.)

In consideration of these possibilities, we thought it worth while to make a study of the effect of the precipitation by carbonic acid gas on the fungicidal value of lime-sulfur solution and its various modifications. For our laboratory tests, a carbon dioxid generator was

used, passing the gas through the various preparations. The action was always continued until some time after the solution had become colorless. The preparation was kept well agitated while spraying the slides to insure even distribution of the precipitate. Spore germination tests were then made, as described in the introduction. Table 3 gives the average results of not less than seventy comparative experiments which were performed at different dates, using different concentrations and several modifications of lime-sulfur solution, and comparing the precipitated with the not-precipitated solutions.

TABLE 3—EFFECT OF PRECIPITATION BY CARBON DIOXID ON LIME-SULFUR AND ITS VARIOUS MODIFICATIONS

Conidia of *Sclerotinia fructigena*. Per cent germinated

Treatment	Precipitated		Not Precipitated	
	Treated	Check	Treated	Check
Lime-sulfur 1-200.....	6.6	80.3	6.2	40
Lime-sulfur 1-150.....	5	50	7.5	40
Lime-sulfur 1-100.....	7.2	67.7	9.6	67.5
Lime-sulfur 1-50.....	3.3	55	0.4	38
Lime-sulfur 1-25.....	0	47	0	23.5
Lime-sulfur 1-200 + lead arsenate.....	1.6	53.7	1.8	56
Lime-sulfur 1-150 + lead arsenate.....	0	66	0	48.5
Lime-sulfur 1-100 + lead arsenate.....	t	83.3	t	22.5
Lime-sulfur 1-50 + lead arsenate.....	0	50	0	36.2
Lime-sulfur 1-200 + lead arsenate + lime...	0	76.2	t	45
Lime-sulfur 1-100 + lead arsenate + lime...	0	65	0	62.5
Lime-sulfur 1-200 + lead arsenate + iron sulfate.....	6.5	80	7.7	61.3
Lime-sulfur 1-200 + iron sulfate.....	3.5	80	t	46.6
Lime-sulfur 1-200 + lime.....	0	59	t	49.7
Lime-sulfur 1-100 + lime.....	0	43	1	56.6
Filtrate lime-sulfur 1-10.....	4	47		
Filtrate lime-sulfur 1-10; spores directly in filtrate.....	t	35		

For every experiment with precipitated lime-sulfur, there was a corresponding one made at the same date with the same concentration, same modifications, same preparation of spores, and in every way similarly treated except that the lime-sulfur was sprayed on the slides in soluble form. In these experiments, only conidia of *Sclerotinia fructigena* were used. Averaging the percentages of germination on slides sprayed with all combinations and concentrations treated with the gas, we have 3% on the sprayed and 50% on the check ends of the slides. The average from the same combinations and concentrations

when the gas was not used was 6% on the sprayed and 67% on the unsprayed ends of the slides. The precipitated preparation here really shows a lower percentage of germination, but since the checks run correspondingly lower we conclude that the precipitation by the gas did not materially increase or decrease the fungicidal value. (See Pl. 1, Figs. 3, 4, 6.)

In Mr. Green's orchard at Sodus, Greening trees were similarly sprayed with the gas sprayer in comparison with bordeaux mixture. Here also the precipitated lime-sulfur controlled the scab well.

To check up our laboratory experiments with results on the trees, some spraying experiments on apples and peach trees were planned and carried out during the summer of 1910. Several Greening and Hubbardston apple trees were sprayed with commercial lime-sulfur diluted 1-30, to which was added 2 pounds of lead arsenate to 50 gallons of solution. This was applied with a hand pump sprayer. Several others of the same varieties were sprayed with the same preparation, applying it with the gas sprayer and allowing the gas to stand in contact with the solution about one-half hour before starting to spray, so as to insure complete precipitation of the soluble sulfur. The mixture was kept thoroughly agitated to insure equal distribution of the precipitate. Table 4 records the results:

TABLE 4—SHOWING RESULTS OBTAINED ON APPLES SPRAYED WITH LIME-SULFUR AND ARSENATE OF LEAD PRECIPITATED BY THE GAS SPRAYER, COMPARED WITH THE SAME NOT SO PRECIPITATED

Mr. Baxter's Orchard

Variety	Lime-sulfur 1-30 + lead arsenate 2-50		Check
	% Scab Precipitated	% Scab Not Precipitated	% Scab
Hubbardston	6.1	3.3	94.0
R. I. Greenings	7.1	10.9	79.4

Similar experiments were tried on peach trees. As previously stated we had hoped by precipitating the soluble sulfur before applying it to be able to avoid all danger of foliage injury. Several trees in two different orchards were sprayed with lime-sulfur diluted 1-30, and others with lime-sulfur diluted 1-50, in each case with 2 pounds arsenate of lead

to 50 gallons added. The gas sprayer was used. Serious foliage injury was caused; in fact, almost total defoliation resulted. There was also a larger percentage of rotted fruit on the trees thus treated than on the unsprayed trees. We attribute this, however, to the fact that the foliage injury so devitalized the trees that they were unable properly to mature the fruit. The injury was due probably to arsenic being in some way made soluble in the series of reactions through which it had passed, as has been pointed out by the senior author ('11). This conclusion was further confirmed when the trees sprayed with lime-sulfur 1-30 alone, without the lead arsenate, precipitated by the gas sprayer in a similar way, suffered no injury whatever; and in this case the brown rot was reduced from 45% on checks to 1.5% on the tree sprayed twice and to 6.5% on the two trees sprayed only once. Here we have evidence from field tests that the precipitation did not destroy the fungicidal value of lime-sulfur solution used alone for brown rot of peach. So far as its use with lead arsenate is concerned, we were prevented from getting results on peaches because of the severe foliage injury caused by the arsenic. The results on apple scab given above furnish evidence on this point.

We would hesitate, however, to advise the use of the gas sprayer to apply lime-sulfur and lead arsenate, even on apples, until given further trial. In view of the results on peach foliage, we fear that there might be some danger that under certain conditions enough soluble arsenic would be liberated to cause objectionable injury to the foliage of the apple. In the case cited above, some slight yellowing and dropping occurred about a month after the application, but not enough to be very objectionable.

So far as determining its fungicidal value is concerned, we should consider this test a severe one, since the spring and early summer were very favorable for fungus infection. The precipitation does seem to reduce to some extent the adhesive qualities of the preparation, and for this reason it might not prove so effective under all conditions.

('11) Wallace, E. Spray Injury Induced by Lime-sulfur Preparations, N. Y. (Cornell) Agr. Exp. Sta. Bul. 288: 1. c. 120. 1911.

TESTS OF THE EFFECT OF THE ADDITION OF LIME TO LIME-SULFUR SOLUTION

Table 5 gives the results of laboratory tests on this point.

TABLE 5—SHOWING THE EFFECT ON SPORE GERMINATION OF THE ADDITION OF LIME TO LIME-SULFUR SOLUTION

Treatment	Sclerotinia fructigena. Per cent germinated			
	Treated + lime	Check	Treated	Check
Lime-sulfur 1-200.....	t	49.7	6.2	40
Lime-sulfur 1-100.....	1	56.6	9.6	67.5
Lime-sulfur 1-200 pptd.....	o	59.0	6.6	80.3
Lime-sulfur 1-100 pptd.....	o	43.0	7.6	67.7
Lead arsenate 2-50.....	t	70.0	56.9	78.8
Lime-sulfur 1-200 + lead arsenate.....	t	45.0	1.8	56
Lime-sulfur 1-100 + lead arsenate.....	o	62.5	t	72.5
Lime-sulfur 1-200 + lead arsenate pptd.....	o	76.2	1.6	53.7
Lime-sulfur 1-100 + lead arsenate pptd.....	o	65.0	t	83.3

In some cases there seemed to be some increase in the efficiency of lime-sulfur solution due to the addition of lime. The number of experiments in which this occurred, however, is not great enough to establish the principle. This is true both of lime-sulfur alone and of lime-sulfur with lead arsenate added. A large number of comparative tests would be necessary to establish this point. On the other hand, there seemed to be a marked increase due to the addition of lime when the mixture was precipitated by carbonic acid gas.

This again might be explained on a purely physical basis. When lime-sulfur solution is treated with carbon dioxid in a test tube, it will be noticed that a very fine quite adhesive deposit is made on the sides of the tube. The particles of lime present are very much coarser than the particles of this deposit. It is probable that this same deposit is made and that it coats the surface of each particle of lime in the mixture. Now when a viable spore lodges in a drop of water on a sprayed surface, its germination is apparently prevented in one of two ways: either the dissolving action of water on the spray material brings a sufficient amount of a toxic substance into solution to prevent spore germination, or the spore may secrete a dissolving agent which in turn acts on the spray material. In either case, the explanation on a physical basis would be the same. A greater surface is exposed to the dissolving action and a germination-inhibiting strength could be more quickly obtained. This principle should also apply to any additional value that

might appear in case of the solution not so precipitated, except that in this case the particles of lime would become coated as the solution dries around them. In any case, this result might obtain in laboratory tests while it would not hold true in actual practice where the spray would be subjected to the action of the rain. In the latter case, the spray-coated particles of lime would probably not adhere so well as the finer coating deposited directly from the solution. If these particles are washed off, the surface may be left more bare than if they had not been present. The result would be to decrease the effectiveness of the spray. The fact that lead arsenate alone controlled apple scab better than with magnesium oxid or with sediment from pure lime added, while the reverse was true in the laboratory tests, would seem to add some weight to this conclusion.

We have accumulated some evidence that the explanation of the fundamental principle of fungicidal action involved in the preceding paragraph represents the actual condition.

THE PRINCIPLE OF FUNGICIDAL ACTION

To determine whether or not the spore is active in dissolving the material that prevents germination, two types of experiments were performed. While they have not yet been carried out on so extensive a scale as desirable, we believe that the results are sufficiently striking to be worthy of note as an indication of what is probable, and as a suggestion for further work in this connection.

Drops of water were placed on slides that had been sprayed with lime-sulfur solution 1-50. The water was allowed to stand on the spray-coated surface for two days. It was then transferred to clean slides, and conidia of *Sclerotinia fructigena* were added. This reduced germination on the three slides thus treated only from 98% to 75%, but growth was markedly inhibited. It would therefore appear that the water itself was able to dissolve some of the toxic substance but not enough to account for the fungicidal action when the spores are placed in the water directly on the spray-coated surface. It would seem, then, that the germinating spore secretes a dissolving agent which acts on the insoluble fungicide to bring small quantities of the same into solution. (See Pl. 1, Figs. 3, 9.) To get further evidence on this point, the following experiments were devised and carried out with the aid of suggestions from Professor Whetzel.

Spores of the same fungus were placed in water in a watch-glass for three days to germinate. The spores were then filtered out. Hypothetically, this should give us water plus the dissolving agent secreted by

the spores. Some drops of the filtrate were placed on slides sprayed with lime-sulfur 1-25 and some on clean slides. Germination tests in water in which no spores had previously germinated were carried through the entire experiment as a check. All slides were kept in moist chambers for two days, then the water from each slide was removed to clean ones, and spores added, with the results shown in Table 6.

TABLE 6

Treatment	No. Slides	Per cent germinated	Remarks
Check.....	2	40	Vigorous growth.
Water from sprayed slides.....	5	8	Growth much inhibited.
Water+hypothetical dissolving agent from sprayed slide.....	3	0	
Water+dissolving agent from unsprayed slide.....	1	25	Growth somewhat inhibited.

This experiment was repeated with somewhat similar results, using lime-sulfur 1-50 on the sprayed slides, and allowing the water and water plus dissolving agent to stand only 28 hours on the sprayed slides. Conidia of *Sclerotinia fructigena* were again used.

The individual slides were as shown in Table 7.

TABLE 7

	Per cent germination
Water from sprayed slides.....	7
" " " "	14
" " " "	20
" " " "	4
" " " "	10
" " " "	10
" " " "	10
" " " "	12
" " " "	8
Water+hypothetical dissolving agent from sprayed slides.....	1
" " " " " " " "	1
" " " " " " " "	1
" " " " " " " "	1
" " " " " " " "	5
Water+hypothetical dissolving agent from unsprayed slides.....	30
" " " " " " " "	10
" " " " " " " "	30
" " " " " " " "	50
" " " " " " " "	50

These experiments are not sufficiently extensive to conclusively demonstrate our point. They certainly show, however, that there is some intimate relation between the action of the spore on the relatively insoluble fungicide and the action of the fungicide on the spore.

Further, germination tests directly on sprayed slides have given evidence that close contact of the spore with the fungicidal coating is an important factor, at least in some cases. This was especially noticeable when conidia of *Glomerella rufomaculans*, the bitter rot fungus, were placed to germinate on slides sprayed with lime-sulfur solution. Table 8 was compiled from actual counts made from a number of fields selected from the clear spaces between the spray-coated spots on the slide compared with others selected directly on the spray-coated spots. The same drop of water covered all the field in each case, so that if the fungicide went into solution in sufficient quantity to be effective without the aid of the spores, its action should be evenly distributed throughout the drop of water by means of diffusion. However, there is also in this case the possibility that even though the water were the only dissolving agent, the spore lying directly in contact with the source of the solution would absorb it before diffusion had taken place.

In concluding this discussion, we wish to point out that the principle of fungicidal action may not be the same in all fungicides and may also vary with different fungi. The above experiments apply only to lime-sulfur as affecting the fungi used in these experiments. In the case of the experiments on *Glomerella*, two slides sprayed with bordeaux 4-4-50 were used and on these germination was prevented about as much on the clear space as on the spray-coated spots directly. If this phenomenon holds constant, it might explain why bordeaux may be expected to control bitter rot more successfully than lime-sulfur solution.

TESTS OF THE EFFECT OF THE ADDITION OF IRON SULFATE TO LIME-SULFUR SOLUTION

The number of experiments conducted on this phase of the subject was rather small, and we should hesitate to draw definite conclusions.

The addition of iron sulfate to lime-sulfur solution, so far as our laboratory tests are concerned, seemed to have but very little effect on the efficiency of the latter; if any, perhaps slightly increasing it. The results are shown in Table 9 and more in detail in Table 12, page 203, and are not entirely consistent. The same tables, however, seem to show that when lead arsenate and iron sulfate are both added, the increased value due to the addition of arsenate of lead is not realized as it is when the iron sulfate is omitted. This will be further noted

TABLE 8—SHOWING THAT CONIDIA OF *GLOMERELLA RUFOMACULANS*, WHEN IN DIRECT CONTACT WITH SPRAY-COATED SURFACE, ARE PREVENTED FROM GERMINATING AND FROM PRODUCING APPRESSORIA MUCH MORE EFFECTIVELY THAN WHEN LYING ON UNSPRAYED SURFACE, BETWEEN DROPS OF SPRAY.

Counts made from same slide in the same drop of water

Treatment	On clear space between spray drops			On spray-coated spot		
	No. spores germinated in each field counted	No. not germinated in each field counted	No. appressoria in each field counted	No. spores germinated in each field counted	No. not germinated in each field counted	No. appressoria in each field counted
Sprayed lime-sulfur 1-50	4	13	5	0	27	0
"	13	8	9	0	18	0
"	15	11	8	0	22	0
"	12	13	10	0	13	0
"				0	20	0
Sprayed lime-sulfur 1-100	6	9	4	2	18	2
"	8	13	9	0	13	0
"	14	6	17	0	14	0
"	9	6	13	0	20	0
"	4	13	2	0	23	0
"				0	21	0
"				0	11	0

by comparing these tables with Table 2. The same was true also when the mixture was precipitated by carbon dioxide.

TABLE 9—SHOWING EFFECT OF THE ADDITION OF IRON SULFATE TO LIME-SULFUR SOLUTION ON GERMINATION OF CONIDIA OF SCLEROTINIA FRUCTIGENA

Treatment	Sclerotinia fructigena. Per cent germinated			
	Treated + Iron Sulfate	Check	Treated	Check
Lime-sulfur 1-400.....	0	60		
Lime-sulfur 1-200.....	trace	46.6	6.2	40
Lime-sulfur 1-100.....	3.5	43	9.6	67.5
Lime-sulfur 1-200 precipitated....	3.5	80	6.6	80.3
L. S. 1-200 + arsenate of lead,,,	7.7	61.3	1.8	56
L. S. 1-100 + arsenate of lead....	0	72	trace	48.5
L. S. 1-200 + arsenate of lead pptd.....	6.5	80	1.6	53.7
L. S. 1-50 + arsenate of lead pptd.....	0	40	0	50

THE SEDIMENT

Another much discussed question is the value of the sediment which is sometimes retained in lime-sulfur solution. This point is of special interest to the person who makes his own lime-sulfur, for if the sediment or sludge is of no value it may as well be discarded unless the grower prefers to use it as a marker. It is also of interest to him who buys the factory-boiled product, since it is not worth while to pay freight for a valueless product even though the company should furnish the extra volume, thus occupied, free of charge.

Laboratory tests were made to determine the fungicidal value of sediment from heavy-grade commercial lime-sulfur, and also from two types of home-boiled concentrates. The sediment was prepared for these tests by filtering and washing for two or three days to remove the solution as thoroughly as possible. Twenty-six experiments on sediment from heavy-grade commercial lime-sulfur at various concentrations were conducted and in every case the percentage of germination was considerably reduced both by the sediment alone and when combined with arsenate of lead. As shown in Table 10, however, it did not seem to have as strong fungicidal value as the same volume of the clear solution. Furthermore, the addition of lead arsenate to the sedi-

TABLE 10—SHOWING THE EFFECT OF THE SEDIMENT ON SPORE GERMINATION

Treatment	Sphaeropsis malorum % germination		Venturia inaequalis % germination		Sclerotinia fructigena % germination	
	Treated	Check	Treated	Check	Treated	Check
Sediment from commercial lime-sulfur 1-100.....					17.2	60.5
Sediment from commercial lime-sulfur 1-50.....					4.2	67.7
Sediment from commercial lime-sulfur 1-25.....					.6	57.8
Sediment from commercial lime-sulfur 1-10.....					.0	32.0
Sediment from commercial lime-sulfur 1-100 + lead arsenate.....					9	79.0
Sediment from commercial lime-sulfur 1-50 + lead arsenate.....					4.3	90.7
Sediment from solution made from pure lime 1-100.....					8.8	26.0
Sediment from solution made from pure lime 1-50.....					6.6	35.0
Sediment from solution made with magnesium (25%) lime 1-100.....					.4	25.0
Sediment from solution made with magnesium lime 1-50.....					0.0	20.0
Sediment from solution made with magnesium lime 1-30.....	40	94	0.	74.7		
Sediment from solution made with pure lime 1-30.....	72.5	90	1.	70.0		

ment did not seem to increase its effectiveness so markedly as when added to the solution. This is further evidence that the reaction between lead arsenate and lime-sulfur solution induces a greater increase in the efficiency of the fungicides than would be accounted for by that of lead arsenate itself if it remained as such.

From these tests it would seem that the sediment has about one-half the fungicidal value of the same volume of the clear solution. To demonstrate this, a quantity of it was filtered out, washed for three days, and two Greening trees were sprayed with the sediment diluted 1-15, with 2 pounds arsenate of lead to 50 gallons. The trees were sprayed three times on the same dates that those in the same orchard were sprayed with other preparations. The scab was reduced from 58% to 13% on these trees, practically the same result which was obtained on trees beside them sprayed with lime-sulfur solution 1-30 with arsenate of lead. In view of the fact that arsenate of lead alone has some fungicidal value, it is to be regretted that sediment alone was not used on some trees, but since control was as good as the average where other fungicides were used in the same orchard, and since in another orchard lead arsenate alone gave 29% of scab where lime-sulfur with lead arsenate gave only 3%, there seems to be little doubt that the sediment itself was effective, especially when confirmed by the above laboratory tests on sediment alone. (See Pl. 1, Figs. 3, 4 and 8).

Further experiments both in the field and laboratory were performed to determine if possible to what ingredient or ingredients of the sediment its fungicidal properties are due. According to Van Slyke et al ('09), this sediment is likely to contain 1 to 7% of free sulfur, 13 to 15% calcium sulfite, 9 to 12% magnesium, and a small amount of calcium sulfite, iron and aluminum. By laboratory experiments most of these substances were tested individually, with the results shown in Table 11.

Calcium sulfite seemed to have very little value as a fungicide, and while free sulfur does have value, it is not present in the sediment in sufficient quantities to account for the fungicidal effect.

Magnesium oxid, on the other hand, was effective in preventing spore germination. A concentration of $\frac{1}{2}$ gram to 100 cc. of water in four different experiments made at four different dates entirely prevented germination of conidia of *Venturia inaequalis*. A stronger solution quite effectively reduced the germination of *Sphaeropsis* spores which have been found to be very resistant to fungicides. In all, sixteen experiments were conducted, all of which indicated quite decidedly that magnesium oxid has considerable fungicidal value.

('09) Van Slyke L. L. et al. N. Y. (Geneva) Agr. Exp. Sta. Bul. 319:1. c. 116. 1909.

TABLE II—SHOWING THE EFFECT OF THE VARIOUS CONSTITUENTS OF SEDIMENTS ON SPORE GERMINATION

Treatment	Sphaeropsis malorum % germination		Venturia ineaqualis % germination		Sclerotinia fructigena % germination	
	Treated	Check	Treated	Check	Treated	Check
Calcium sulfite 2 grams per 100 cc.	61	87	40.5	55		
Calcium sulfite 3 grams per 100 cc.	53.5	91.2	26.2	46.5		
Calcium sulfite 4 grams per 100 cc.	62.5	97	23.7	77.5	68	49.5
Calcium sulfate 2 grams per 100 cc.	23.1	93.7	43.4	75.6		
Calcium sulfate 3 grams per 100 cc.	33.7	84.8	15	63.7		
Magnesium oxid $\frac{1}{2}$ gram per 100 cc.	77.5	95	0	69	3	40
Magnesium oxid 1 gram per 100 cc.	47.5	88	0	68.5		
Magnesium oxid 2 grams per 100 cc.	20	92			0	95
Magnesium oxid 3 grams per 100 cc.	16.5	96				
Magnesium oxid 4 grams per 100 cc.	7.5	96				
Sulfur 2 grams per 100 cc.					0	44

To determine whether or not this might largely account for the efficiency of sediment, two home-boiled preparations were made, in one case using chemically pure lime (CaO), in the other adding 25% of magnesium oxid (MgO). This would be equivalent to using magnesium lime. The sediment from each was filtered, washed, and tested as was the sediment of the Niagara heavy-grade. Here the difference was decidedly in favor of the sediment containing the magnesium. Since, however, the checks in either case did not germinate as well as could be desired, we would not consider this test to be absolutely reliable.

This evidence, however, in addition to the results obtained with magnesium, leads us to suspect that the fungicidal value of the sediment will probably vary largely with the magnesium present in the lime used in making the lime-sulfur solution. Probably if a pure lime is used, the sediment itself will have but little fungicidal value. The fact that sediment containing magnesium was more effective than magnesium oxid alone or even with lead arsenate added, might be explained by the fact that the sediment had better sticking qualities than magnesium powder alone or with lead arsenate. Field experiments were planned to confirm or disprove this conclusion. A quantity of each of two kinds of sediment was prepared, as above, and several young trees in Mr. Baxter's orchard were sprayed with each, using the usual amount of lead arsenate in both cases. On Greenings sprayed with the sediment containing lead arsenate but no magnesium, the scab was reduced from 79% to 26% (752 apples included); on Pound Sweets, from 78% to 26% (38 apples included). Adjacent trees were sprayed with sediment known to contain magnesium. Unfortunately the Greening and Hubbardston trees thus sprayed did not set fruit. On the Pound Sweet tree in this plat only 94 apples were found, but the scab on these was reduced from 78% to 9%.

This indicates strongly that the sediment without the magnesium has rather weak fungicidal value. Even lead arsenate alone gave better results on Hubbardstons. This may be due to the better sticking properties of the latter. It does not prove, however, that the other preparation would have given decidedly better results since the number of apples set on this plat was so small that no definite conclusion could be drawn from this experiment. The result on those that did set, however, was encouraging, and in view of the fact that the sediment from the Niagara solution, which probably contains considerable magnesium, gave such satisfactory results in Mr. Legassee's orchard, we are inclined to believe that, on this point also, field results will agree with those obtained by laboratory experiments.

On the other hand, we were not able by our field experiments on apples to confirm the results of our laboratory tests on magnesium oxid itself. This was used at the rate of one pound to five gallons with the usual amount of lead arsenate. Scab on Greenings was reduced from 79% to 39%, and on Hubbardstons from 94% to 45%. Lead arsenate alone, the same strength, reduced scab on the Hubbardstons to 29%.

This result was somewhat anticipated in view of the very poor sticking qualities of the magnesium powder even when mixed with lead arsenate. We might again explain on a purely physical basis the fact that lead arsenate on apples was more effective alone than with magnesium oxid or even with the pure lime sediment, in that the arsenate being applied with and on the solid particles of the powder, is partially removed with the latter by rains, etc. (See p. 175.)

On peaches, however, magnesium oxid alone was quite effective in controlling the scab fungus (*Cladosporium carpophyllum*). On a tree of Early St. John's sprayed with magnesium oxid without any lead arsenate added, there was but 3½% of scab as compared with 44% on the two adjoining trees unsprayed. The difference here was certainly marked enough to demonstrate in this case the fungicidal value of magnesium oxid, and since the downy coat of the peach helps the preparation to adhere, even though it be a poor sticker, it further seems evident that the failure to control scab on apples was due to poor adhesive qualities and not to a lack of fungicidal properties.

In concluding the discussion of magnesium oxid and sediment, we wish to make it clear that we are not recommending the use of magnesium or impure lime for the preparation of lime-sulfur solution, nor in general, the use of sediment. We have been trying to get at the fundamental principles involved.

Even though the fungicidal value of magnesium oxid be demonstrated, it does not demonstrate the advisability of using magnesium lime in preparing the solution. It would doubtless be somewhat wasteful if the sediment is to be discarded, since the magnesium, we are told by VanSlyke et al ('09), does not to any extent go into solution, but remains with the sediment, and would therefore, be discarded with it. Again, since magnesium remains insoluble, considerable more sediment is formed when it is present in the lime used, and this to some persons may be rather objectionable. It is also true, as noted by VanSlyke ('09), that in cooking considerable hydrogen sulfid (H_2S)

('09) VanSlyke, L. L. & Hedges, C. C. & Bosworth, A. W. N. Y. (Geneva) Agr. Exp. Sta. Bul. 319: 1 c. 410-411. 1909.

is formed when magnesium lime is used. This is unpleasant and unhealthy for workmen, and also results in the loss of some sulfur. All these points must be considered in a discussion of the practical phase of the subject but are beyond the scope of our present work. Our work, in brief, indicates only that magnesium oxid itself has fungicidal value and that the sediment from a solution, especially when made from lime high in magnesium content, is evidently worth using with the solution and should therefore not be discarded as a worthless product. It is probable that if the sediment is used with the solution there is no loss of fungicidal value from the use of magnesium lime since the magnesium itself would probably more than atone for the loss of the small amount of sulfur which it occasions. It is probably true, however, that the greater inconvenience occasioned by the presence of magnesium in preparing the mixture and the formation of a larger amount of sediment makes it desirable to use pure lime. Whether one should purchase a commercial solution with or without the sediment is another question which we are not attempting to discuss here. Our work again simply indicates that the sediment from the preparation we tested, itself had about one-half as much fungicidal value as the same volume of the clear solution.

SUMMARY

It is generally conceded that in most cases fungicides control fungous diseases of plants by preventing spore germination. Therefore, any laboratory method of testing the value of a fungicide for such diseases must be based on spore germination tests and any such method to be of practical significance must be one in which the fungicide is brought in contact with the spores in as nearly as possible the form in which it is found when called upon to prevent infection of the plant.

Tests made directly in the solution or mixture as it occurs in the spray tank do not conform to this condition since most fungicides undergo marked chemical changes on exposure to atmospheric conditions after being applied to the plant. The method, therefore, should be one in which the fungicide is subjected to such changes before the test is made. When glass slides are sprayed and subjected to atmospheric conditions for a time before the germination tests are made, this condition is at least approximated. This method does not determine all points of efficiency in a fungicide. We believe it quite accurately indicates the fungicidal properties of a substance. Other properties may largely determine its practical efficiency, such as a proper degree of solubility and the adhesiveness of the material. Other methods

must be employed to test these points. Perhaps some washing process may be used successfully. The method employed in this work could not be used in a study of such fungous diseases as powdery mildews, where the fungicide destroys the surface-growing fungus by direct contact. It is also probable that in the case of peach leaf curl the spores are killed by direct contact with the spray as applied, in which way it differs in principle from most fungous diseases and our method would therefore not be applicable to this disease.

No generalization can be made applicable to all fungous diseases. Each disease must be studied separately, first knowing the life history of the fungus and governing the study of the fungicidal tests accordingly. Lime-sulfur solution at a strength safe for foliage was found by both laboratory and field tests to be only fairly effective as a fungicide. In general, a stronger concentration was required to prevent germination of conidia of *Venturia inaequalis* than those of *Sclerotinia fructigena*, and still stronger was required for *Sphaeropsis malorum*.

Arsenate of lead alone seems to have some fungicidal value, giving rather better results in field tests than laboratory experiments indicated. This is probably explained by its excellent adhesive properties, in that it keeps the surface of the host so thoroughly coated as to prevent the entrance of the germ tube even though germination of the spores may not be prevented.

Our experiments, both in the field and laboratory, have demonstrated beyond a doubt that the addition of arsenate of lead very greatly increases the fungicidal properties of lime-sulfur solution. The increase seems more marked than could be attributed to the rather weak fungicidal value of arsenate of lead itself, and we therefore conclude that the chemical reaction which takes place when the two substances are combined is beneficial rather than detrimental.

The action of carbonic acid gas on the lime-sulfur solution (as in the case of the use of the gas sprayer), although entirely changing its chemical composition, did not in our tests materially affect its fungicidal value. The soluble sulfur is precipitated before application and the resulting product seems as effective as the relatively insoluble compounds to which the solution would otherwise soon change on exposure to the air after being applied in the soluble form. This seemed true both of lime-sulfur alone and with lead arsenate added. In case of tender foliage, however, there is danger of injury from arsenic when the two combined are so precipitated. On the other hand, with lime-sulfur alone, the action of the gas by precipitating the soluble sulfur seems to destroy entirely its caustic properties, as would be ex-

pected, making it absolutely harmless to foliage. It is probable that the adhesive properties of lime-sulfur thus precipitated before application are not quite so good as when it is applied in the soluble form, although the results of spraying experiments this season (1910) under quite trying conditions were good. Further investigations of this subject are desirable.

The addition of lime to lime-sulfur solution, according to a limited number of laboratory experiments, seemed slightly to increase its efficiency. In field tests no difference that could be attributed to the addition of lime could be noted. The evidence on this point is not conclusive further than that we are convinced that there is no marked effect one way or the other.

The addition of iron sulfate, according to laboratory tests, seemed slightly to increase the fungicidal properties of lime-sulfur solution when no arsenical was used. When lead arsenate was combined with the two, the increased efficiency due to the lead arsenate did not seem to be realized as when the iron sulfate was omitted. Field tests on this point are inconclusive.

Sediment from a commercial solution in the laboratory seemed to show about one-half as much value as the same volume of the solution. This conclusion was confirmed by a field test. Sediment from home-boiled preparations in which magnesium lime was used seemed to have considerably more value than when pure calcium oxid was used. Field tests favored this conclusion, but the number of apples setting on trees thus sprayed was so small that this point is still open to question. If this holds true the value of sediment will vary largely with the magnesium content of the lime used.

Calcium sulfite and sulfate, other ingredients of sediment, were tested and found to have but very little fungicidal value. Free sulfur doubtless has fungicidal value, but the amount of this contained in the sediment is hardly enough to account for the fungicidal properties of the latter.

A study of the principle of the action of the fungicides in preventing spore germination gave some evidence that the spore itself is active in bringing into solution small quantities of the fungicide which in turn prevents germination. Some inhibition is occasioned without the action of the spores, as indicated by the fact that spores germinated more abundantly in water that had stood on sprayed slides for a time and was then removed than in water not so treated. The inhibition was not nearly so marked, however, as when water in which spores had germinated was filtered, placed on slides that had been sprayed, removed, and used for tests.

DATA SHEETS

TABLE 12 —SHOWING RESULTS OF INDIVIDUAL TESTS, EACH INCLUDING 3 TO 5 SLIDES

Spray used	Date 1910	Sphaeropsis malorum % germination		Venturia inaequalis % germination		Sclerotinia fructigena % germination	
		Treated	Check	Treated	Check	Treated	Check
Lime-sulfur 1-200	2-21					0	10
	2-21					0	50
	2-21					2	50
	2-21					20	50
	2-21					2	20
	2-26					25	90
	3-1					3	75
	3-18					0	40
	3-28					0	25
	4-1					0	20
	4-1					0	10
	4-1					1	20
	4-4					28	60
L. S. 1-150	2-25					t	30
	4-1					0	10
	4-4					22.5	80
L. S. 1-100	1-26					5	15
	1-28					2.5	15
	2-5					2	44
	2-8					8	90
	2-8					17	69
	2-9					15	98
	2-17					39	58
	2-20					15	92
	2-20					6	92
	2-25					t	45
	2-25					0	90
	2-25					0	90
	2-26					36	90
	2-26					43	90
	2-28					0	90
	3-1					0	80
	3-9					4	26
	3-9					t	70
	3-9					0	80
	3-18					t	25
	6-27	86	89	43	73		
	7-11	92.5	96				
	7-13			55	90		
	7-28	66.6	74.5	43.5	88		
L. S. 1-50	'09						
	10-8					1.8	40
	10					0	42
	1-10					0	22

TABLE 12 (Continued)—SHOWING RESULTS OF INDIVIDUAL TESTS, EACH INCLUDING 3 TO 5 SLIDES

Spray used	Date 1910	Sphaeropsis malorum % germination		Venturia inaequalis % germination		Sclerotinia fructigena % germination	
		Treated	Check	Treated	Check	Treated	Check
L. S. 1-50	2-13					t	48
	6-27	66	83	1.5	56		
	7-8	71	83.5				
	7-11	86.5	94	27.5	96.5		
	7-25	63	78	10.5	56		
L. S. 1-30	6-27	51	90	12.5	63.5		
	7-11	77.5	96.5				
	7-13			15	82.5		
	7-28	62.5	73.5				
L. S. 1-25	12-15					0	47
	12-27					0	0
L. S. 1-20	7-28	50	80	10	75		
	7-28	58	84	5	85		
L. S. 1-10	7-28	15	95	t	93		
	7-28			t	84		
L. S. 1-200 + lead arsenate	2-21					0	30
	2-26					7.5	90
	2-26					0	50
	3-1					t	85
	3-9					3.3	50
	3-18					t	40
	3-18					0	30
	4-4					3.6	73
L. S. 1-150 + lead arsenate	3-9					0	40
	3-9					0	57
L. S. 1-100 + lead arsenate	2-8					0	95
	2-9					0	98
	2-9					t	98
	2-17					0	55
	2-17					0	50
	2-20					0	92
	2-25					0	40
	3-1					t	85
	3-18					0	40
	6-27	30	96	0	85		
	7-11	47.5	94				
	7-13			2.5	87.5		
L. S. 1-50 + lead arsenate	1-11					0	50
	1-28					0	50
	4-4					0	10
	4-4					0	15

TABLE 12 -(Continued)—SHOWING RESULTS OF INDIVIDUAL TESTS, EACH INCLUDING 3 TO 5 SLIDES

Spray used	Date 1910	Sphaeropsis malorum % germination		Venturia inaequalis % germination		Sclerotinia fructigena % germination	
		Treated	Check	Treated	Check	Treated	Check
L. S. 1-50 + lead arsen- ate	6-27	10	75	0	90		
	7-8	11.5	74	0	45		
	7-11	37.5	98				
	7-13			2.5	91		
L. S. 1-30 + lead arsen- ate	6-27	15.5	95	0	42		
	7-8	0	87.5				
	7-11	9.5	91				
	7-13			0	30		
	7-28	6.2	74	0	75		
L. S. 1-20 + lead arsen- ate	7-28	6	92	0	80		
	7-28	2	68	0	92		
L. S. 1-200 pre- cipitated	3-1					4	85
	3-9					t	80
	4-4					16	76
L. S. 1-150 ppt.	2-25					0	65
	2-25					10	35
L. S. 1-100 pre- cipitated	2-8					2.5	69
	2-8					8.5	90
	2-9					7.5	?
	2-17					2.5	58
	2-17					.5	58
	2-20					2.5	92
	2-25					15	90
	2-26					25	90
	3-1					3.5	90
	3-25					5	40
L. S. 1-50 pre- cipitated	'09						
	10-10					11	62
	12-15					0	93
	'10						
L. S. 1-25 pre- cipitated	4-4					0	10
L. S. 1-200 + lead arsen- ate precip- itated	2-15					0	47
	2-26					1	90
	2-26					0	65
	3-1					2.5	85
	3-9					6.5	56
	4-1					0	10
	4-1					0	10
	4-4					1	60

TABLE 12 (Continued)—SHOWING RESULTS OF INDIVIDUAL TESTS, EACH INCLUDING 3 TO 5 SLIDES

Spray used	Date 1910	Sphaeropsis malorum % germination		Venturia inaequalis % germination		Sclerotinia fructigena % germination	
		Treated	Check	Treated	Check	Treated	Check
L. S. 1-150 + lead arsen- ate precip- itated	? 4- 4					o o	57 75
L. S. 1-100 + lead arsen- ate precip- itated	2- 8 2- 9 2- 9 2-17 ? ? 2-20 2-25 3- 1					o o t o o o o o o	95 98 98 55 50 81 92 90 90
L. S. 1-50 + lead arsen- ate precip- itated	1-11 1-28					o o	50 50
L. S. 1-200 + lead arsen- ate + lime	3- 1 3- 9					o t	25 65
L. S. 1-100 + lead arsen- ate + lime	2-25 2-26					o o	35 90
L. S. 1-200 + lead arsen- ate + lime precipitated	3- 1 3- 9					o o	62.5 90
L. S. 1-200 + lead arsen- ate + iron sulfate	3- 1 3- 9 4- 1 4- 4					3.5 26 o 1.3	80 83 5 60
L. S. 1-100 + lead arsen- ate + iron sulfate	3-18					o	72
L. S. 1-200 + lead arsen- ate + iron sulfate pre- cipitated	3- 1					6.5	80

TABLE 12 -(Continued)—SHOWING RESULTS OF INDIVIDUAL TESTS, EACH INCLUDING 3 TO 5 SLIDES

Spray used	Date 1910	Sphaeropsis malorum % germination		Venturia inaequalis % germination		Sclerotinia fructigena % germination	
		Treated	Check	Treated	Check	Treated	Check
L. S. 1-50 + lead arsen- ate + iron sulfate ppt.	4- 1					0	40
L. S. 1-200 + iron sulfate	3- 9					1	70
	3-10					t	85
	3-18					0	63
	3-26					0	25
	4- 1					0	30
	4- 1					0	30
	4- 1					0	30
	4- 1					0	20
	4- 4					t	66
L. S. 1-100 + iron sulfate	3- 1					0	35
	3- 9					17.5	85
	3-18					0	60
	3-26					0	25
	4- 1					0	10
L. S. 1-100 + lead arsen- ate + lime precipitated	2-25					0	40
	2-26					0	90
L. S. 1-400 + iron sulfate	3- 9					0	60
L. S. 1-200 + iron sulfate precipitated	2-27					3.5	80
L. S. 1-100 + magnesium oxid	3-18					0	45
	3-26					0	46
L. S. 1-200 + lime	3-18					t	66
	4- 1					0	10
	4- 4					0	73
L. S. 1-100 + lime	2-25					3	35
	3- 1					0	50
	3- 9					t	85
L. S. 1-200 + lime precip- itated	3- 1					0	55
	3- 9					0	55
	4- 4					0	67

TABLE 12—(Continued)—SHOWING RESULTS OF INDIVIDUAL TESTS, EACH INCLUDING 3 TO 5 SLIDES

Spray used	Date 1910	Sphaeropsis malorum % germination		Venturia inaequalis % germination		Sclerotinia fructigena % germination	
		Treated	Check	Treated	Check	Treated	Check
L. S. 1-100 + lime precip- itated	2-25					0	35
	2-26					0	75
	3- 1					0	45
	3- 9					0	45
	3-18					0	15
Heavy-grade sediment 1- 100	1-28					t	17
	1-28					t	18
	1-28					30	95
	2- 8					47	95
	2-17					0	57
	2-20					11	92
	2-21					50	80
	4- 1					10	20
	4- 4					7	70
Heavy-grade sediment 1- 50	1- 6					0	22
	1-10					0	50
	2- 8					5	95
	2- 8					15	30
	2-20					t	92
	2-26					10	95
	2-26					t	90
Heavy-grade sediment 1- 25	12-29					0	32
	1-10					2	95
	1-10					0	50
	1-10					0	90
	1-16					1	22
Heavy-grade sediment 1- 10	12-29					0	32
Sediment 1- 100 + lead arsenate	2-20					22	95
	2-20					0	92
	4- 1					5	50
Sediment 1-50 + lead ar- senate	2-20					0	92
	2-26					3	90
	2-26					10	90
Sediment from solution made with pure lime 1- 100	2-21					5	5
	3-28					20	30
	4- 1					10	50
	4- 1					1	40
	4-18					8	5
Sediment from pure lime 1-50	3- 8					12	30
	4-18					0	40

TABLE 12 (Continued)—SHOWING RESULTS OF INDIVIDUAL TESTS, EACH INCLUDING 3 TO 5 SLIDES

Spray used	Date 1910	Sphaeropsis malorum % germination		Venturia inaequalis % germination		Sclerotinia fructigena % germination	
		Treated	Check	Treated	Check	Treated	Check
Sediment from pure lime 1-30	7-8	72.5	90	1	70		
Sediment from solu- tion made with mag- nesium lime 1-100	3-28					0	30
	4-1					0	25
	4-1					0	40
	4-1					0	10
	4-4					0	30
	4-4					3	30
	4-4					0	10
Sediment from mag- nesium lime 1-50	3-28					0	30
	4-1					0	10
Sediment from mag- nesium lime 1-30	6-27	53	95.5	0	87.5		
	7-8	27.5	92.5	0	62		
Lead arsenate 2 pounds to 50 gallons	2-7					60	95
	2-8					48.2	30.2
	2-9					86.5	98
	2-20					33	92
Lead arsenate 1-200	7-8	70.5	88	17.5	47.5		
	7-28	70	86	52.5	88.5		
Lead arsenate + lime	3-16					t	70
Magnesium ox- id 1-200	3-18					6	60
	3-28					0	20
	6-27			0	80		
	7-2	77.5	95	0	58		
	7-8			0			
Magnesium ox- id 1-100	6-27	41	94	0	87		
	7-2			0	50		
	7-8	54	82				
Magnesium ox- id 2-100	3-18	0	95(?)				
	7-2	10	95				
	7-2	0	96				
	7-11	40	97				
	7-11	30	80				
Magnesium ox- id 3-100	7-11	15	95				
	7-11	18	97				

TABLE 12 (Continued)—SHOWING RESULTS OF INDIVIDUAL TESTS, EACH INCLUDING 3 TO 5 SLIDES

Spray used	Date 1910	Sphaeropsis malorum % germination		Venturia inaequalis % germination		Sclerotinia fructigena % germination	
		Treated	Check	Treated	Check	Treated	Check
Magnesium ox- id 4-100	7-12 7-12	5 10	95 97				
Calcium sulfite 2-100	7-11 7-13 7-28	52.5 70	89 85	55 26	79 32		
Calcium sulfite 3-100	7-11 7-13 7-28	57.5 50	92.5 90	32.5 20	65 28		
Calcium sulfite 4-100	2-5 2-17 7-11 7-13 7-28	 55 70	 98 96	 23.5 24	 77.5 77.5	86 50	44 55
Calcium sul- fate 2-100	7-2 7-8 7-11 7-13 7-25	0 0 12.5 80	92.5 95 95 92	29 40 64	51 85 91		
Calcium sul- fate 3-100	7-2 7-11 7-13 7-28	0 27.5 40	91 85.5 78	0 30	40 87.5		
Calcium sul- fate 4-100	7-8 7-11 7-13 7-28	 77.5 75	 94.5 93.5	8.5 27.5 32	53 90 90.5		
Sulfur 2-100	2-5 2-9					0 Inhib- ited	44
Calcium hy- droxid	7-8 7-11	0 0	75 95				
Filtrate from L. S. 1-10 ppt	2-14 2-15		In	filtrate	directly	t 4	35 47
Lead sulfid 1- 100	7-8 7-12 2-28	95 94 57	95 96 79	22.5 40	50.5 57		
Lead sulfid 2- 100	7-8 7-12	90 85	94.5 90	18.5	61		

TABLE 12 -(Continued)—SHOWING RESULTS OF INDIVIDUAL TESTS, EACH INCLUDING 3 TO 5 SLIDES

Spray used	Date 1910	Sphaeropsis malorum % germination		Venturia inaequalis % germination		Sclerotinia fructigena % germination	
		Treated	Check	Treated	Check	Treated	Check
Lead sulfid 4- 100	7-12	85	95				
Self-boiled L. S. 4-4-50	2-26 3- 1					10 2.5	85 20
Self-boiled L. S. 8-8-50	2-26					t	90
Self-boiled L. S. 4-4-50 + lead arsen- ate	3- 1					0	13
L. S. solution made with magnesium lime 1-100	4- 1					2.5	15
Same made with pure lime 1-100	4- 1					12	60
Bordeaux 2-2- 50	3-26 7-28 7-28	 0 0	 72 90	 0 0	 72 80	0	?
Bordeaux 4-4- 50	3-26 7-28 7-28	 0 0	 72 91	 0 0	 46 27	0	?
In fungicide di- rect while in solution 1-20 000	2-28					t	65
Same 1-10, 000						0	65
Same 1-5, 000						0	80

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